Systems and Automation Education through Web-Based Labs

Barry M. Lunt[1], Richard G. Helps[2], Perry Carter[3] and Edward Red[4]

[1]*School of Technology, Brigham Young University, http://www.et.byu.edu/sot/faculty/eet/bl/index.html*
Tel:(1-801)378-2264, Fax(1-801)378-7575, luntb@byu.edu
[2]*School of Technology, Brigham Young University, http://www.et.byu.edu/sot/faculty/eet/rh/*
Tel:(1-801)378-6305, Fax(1-801)378-7575, richard_helps@byu.edu
[3]*School of Technology, Brigham Young University, http://www.et.byu.edu/sot/faculty/mfg/pc/index.html*
Tel:(1-801)378-6305, Fax(1-801)378-7575, carterp@byu.edu
[4]*Department of Mechanical Engineering, Brigham Young University, http://www.byu.edu/me/faculty/red/red.html*
Tel:(1-801)378-6305, Fax(1-801)378-7575, ered@byu.edu

Abstract: We report on the Electronics Assembly and Automation Laboratory (EAAL) at Brigham Young University, which has been developed to teach students modern systems concepts and to address the knowledge required to integrate and trouble-shoot automation devices. Students study topics such as mechanism kinematics, vision system algorithms, I/O control, asynchronous versus synchronous control methods, tooling and sensors, part feeding and orienting, robot calibration, and quality testing.

This paper demonstrates how EAAL's unique open architecture serves both education and research in manufacturing. Laboratory and research experiences are offered both to undergraduate and graduate students using on-line interfaces. Some of the web-based labs can be run off-site, providing a flexible learning and programming environment. Factors affecting the success of web-based labs are discussed.

Keywords: web-based, labs, automation, distance education

1. Introduction

Distance education has long been part of the offerings of many institutions of higher education. With the proliferation of the Internet and the World-Wide Web, most such offerings have become based on this communication technology, and much is presently available. However, the challenge of offering laboratory experiences over the Web remains a significant obstacle in offering distance education in disciplines that require such experiences. An additional challenge is that of exposing students to current technology where such technology is so expensive that only a single system is available.

Attempts are being made, and successes are being reported [1, 2, 3]. Driving this development is the need to make expensive laboratory equipment available to a wider audience and at more times than has been done in the past, and to manage the use of such equipment more effectively. This is the case in the Brigham Young University (BYU) Electronics Assembly and Automation Laboratory (EAAL).

2. The EAAL Facility

The EAAL lab at BYU consists of several pieces of assembly equipment situated around a central conveyor system (see Figure 1). The equipment is designed to allow assembly of a small electronic product, from the assembly of the circuit board up through the assembly of the other parts required for the entire product. This equipment includes two robots, two automated conveyor load/unload stations, parts feeders, a reflow oven, a cleaning station, a manual rework station, a master and a slave computer to control the overall operation, PLCs to control the load/unload stations, and a Profibus system to allow communication between the various pieces of equipment. The controlling computers are also connected to the Internet to permit remote access and control.

EAAL uses the Cimetrix Open Development Environment (CODE) to schedule and control the lab devices using its client-server architecture (see Figure 2). CODE issues slave motion commands to the mechanisms and is interfaced to the Profibus fieldbus for I/O interactions with the various sensors, part handling equipment, conveyor lift gates, and conventional PLC's.

Figure 1. Picture of EAAL Facility at Brigham Young

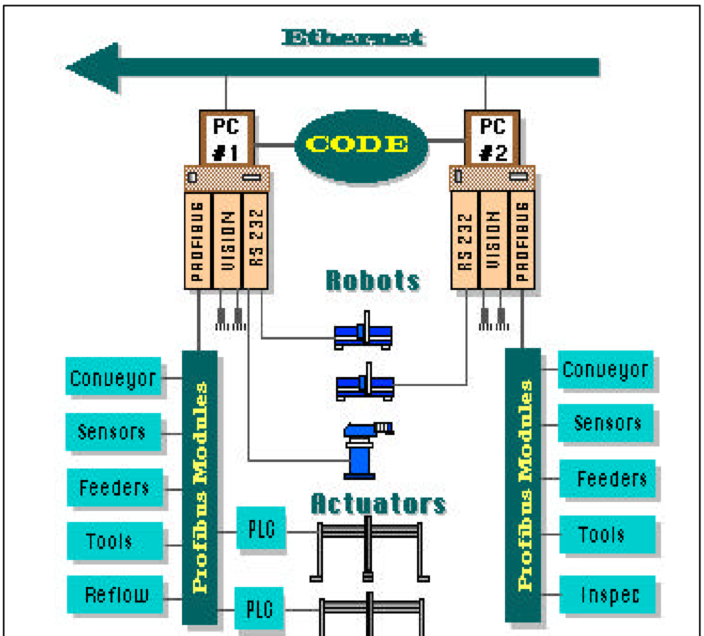

Figure 2. EAAL architecture

Device drivers communicate motion and I/O commands between the CODE server and the native mechanism controllers. A bus-level driver is required to interface CODE to the Profibus fieldbus card supplied by Synergetic. Most EAAL I/O is distributed through the RS 485 fieldbus network.

Figure 3 shows the CODE simulation display of EAAL. Two NT-based PC's are dedicated to assembly operations: one PC to electronics assembly, the other to small parts mechanical assembly. The various devices retain their autonomy when not in the CODE supervisory control mode. This architectural feature allows EAAL to serve both research and education.

3. Lab management

Perhaps the most complicated aspect of combining teaching and research is the scheduling of activities. For example, the lab may be used for data acquisition studies in the morning and a robot tool-changing lab in the afternoon. The open architecture of the design combined with careful scheduling facilitates this multiple use. Because the lab serves multiple programs and departments, a supervisory and scheduling committee sets access rules and scheduling procedures. To this point no more than three classes have used the lab in any term. Scheduling has not yet proven a problem, partly because the on-line labs are

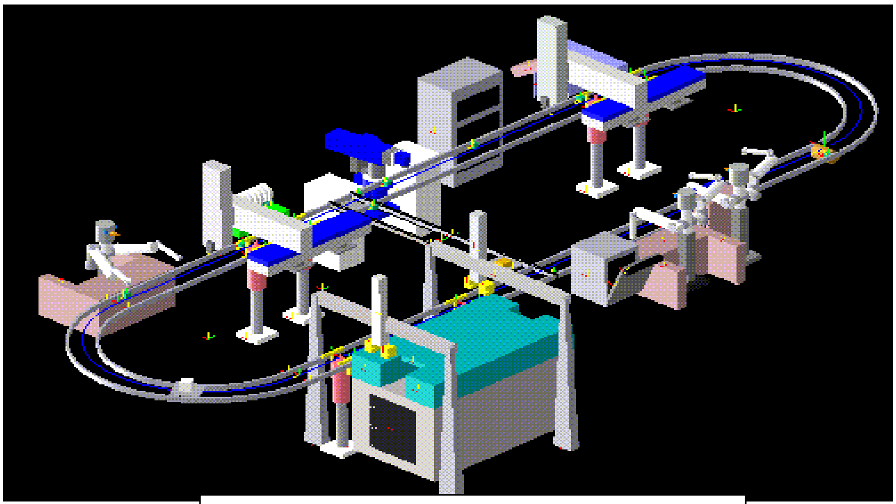

Figure 3. CODE Simulation of EAAL Layout

well organized, with little preparation overhead required of student users. Labs typically require no more than 30 - 45 minutes. Students who have reviewed the on-line lab material at other sites before taking the lab typically take 10 - 15 minutes less to complete the lab assignment. Compare these times to the typical three-hour labs that have been the mainstay of engineering programs for decades. These time savings are consistent with the statement by Robert Galvin [4], Chairman of the Executive Committee, Motorola, that the traditional four-year technical curriculum could be finished in two years.

4. Web-based Lab Organization

The EAAL web-based labs are designed to use an on-line library of web pages that includes all the details and activities necessary for the students to conduct the labs with minimal teaching assistant (TA) guidance. The EAAL Intranet computers also serve to display the lab web pages that are used to conduct the on-line labs. On-line tests are also set up so the students can respond to on-line questions, with multiple choice questions automatically graded, and narrative responses sent to the TA for grading.

Students access the labs through the EAAL web site under the heading ***Education***. The labs available to the various classes are shown and linked. Students simply select the lab they wish to review or to take. Most labs require the students physically be in the lab, but we are developing labs that can be controlled off-site. Details of this for one example lab will be discussed later.

The layout of every lab is consistent. Each lab consists of

- Preliminary Material: Prerequisites, materials, terminology, useful links
- Procedures: Student chooses *direct control* or *net control*; numbered tasks and links to other pages; student records results and observations.
- Evaluation: Student takes on-line quiz and exits lab.

Students can use the preliminary materials and links to understand the pre-requisite materials necessary for the lab. Since these labs focus on emerging system concepts, the section on terminology is important since many of these terms will not be found in modern texts. (See Figure 4)

The procedures are task oriented so that students simply follow step-by-step instructions, record observations and numbers, as the various automation equipment performs tasks. Some of the labs require integrated problem solving. For example, the PLC lab provides a ladder logic control diagram for moving pneumatic actuators. The logic is faulty so that the actuators move incorrectly. The students study an animated graphic simulation of the desired movements and then fix the problem by modifying the ladder logic control diagram.

5. Key Factors in administering Web-based Labs

Perhaps the most exciting development is being able to offer lab experiences using real equipment, but with students controlling the lab from remote sites, ideally any Internet access point. Our experiences in developing these labs have helped us identify several important elements for administering remote labs.

Terminology

Repeatability - Repeatability is the standard deviation of the error between the desired pre-taught coordinate position and the actual robot TCF.

Accuracy - Robot accuracy can be defined as how close a robot tool comes to a point in space which has been programmed but not taught previously. For more information, see :http://www2.et.byu.edu/~ered/robotics/repeatability/repeatability.html

Blob - A single, connected region in a binary or grayscale image.

Calibration - The act of relating X and Y pixel spacing to a known or predetermined pixels per unit length (i.e. inch, mm) factor. Often involves using a template(s) of features with known geometry and some adjustment of the template during the process.

CCD - Charge Coupled Device. A photosensitive image sensor implemented with large scale integration technology.

Lens - A transparent piece of material, usually glass or plastic, with curved surfaces which either converge or diverge light rays. Often used in groups for light control and focusing.

Lens and Camera Distortion - Errors in manufacturing the curved lens will project distorted image geometry onto the CCD, although these errors are usually small. Manufacturing errors in the CCD matrix of pixel sensors will also cause errors in processing an image.

Template - An artificial model of an object or a region or feature within an object. Templates with known geometric objects are used to perform camera calibration.

Thresholding - The process of converting gray scale image into a binary image. If the pixel's gray scale value is above the threshold, it is converted to white. If below the threshold, the pixel value is converted to black.

Vision Coordinates - The coordinate system placed usually at the center or a corner of the vision image field of view. It is used for measuring the relative position and orientation of image features (such as centroid location).

Figure 4. Terminology for Lab 506 "Blob Lab"

The single most important need is for adequate communication between the remote site and the TA in the lab. Firstly we want the student to feel that they are in fact controlling real lab equipment and secondly the student needs to be able to communicate with the TA in the lab, especially if the computer is not working as expected. We tried several methods to achieve this. We used an audible link with Microsoft Netmeeting software initially. We chose Netmeeting because it is widely available and includes several different communication options. While voice contact is extremely useful the Netmeeting channel was not sufficiently reliable for inexperienced users. We later modified this to a keyboard and screen "chat line" through Netmeeting.

To enhance that feeling of being in direct control of the lab we included two cameras. Images are shown in figures 5 and 6 below. One camera just gives a view of the lab and shows the robot moving but is not accurate enough to take any measurements. It does provide the feeling of being in control of the robot. Actions are taken at the remote terminal and the robot is seen to respond. For this reason one of the start-up procedures requires the student to check whether the manipulator lighting system is on. This can be seen easily through the lab scanning camera and helps the students to orient themselves with respect to the robot and the lab.

From our experience so far we feel the essential elements for remote labs are

- Extremely reliable communication. It is necessary for the communication channel to be available even and especially if all other software related to the lab fails.
- Communication that permits a free dialogue between student and TA. A voice channel is excellent if it can meet the reliability standard.
- The ability to signal the lab TA. We are experimenting with audible tones and loudspeakers in the lab.
- Visual and, if possible, audible contact with the lab to enhance the feeling of being in control of the equipment.

6. Test Case: Robotics Blob lab (Lab 506)

Lab 506 is for the class ME 537 – Robotics; the lab is titled simply, "Blob Lab". Its objective is to give the student an opportunity to:

- Estimate robot repeatability
- Estimate robot inaccuracy
- Recognize other sources of vision error such as lens distortion and CCD array resolution
- Understand limitations in simple machine vision processes

Lab 506 begins with an explanation of the related terms (see Figure 4), allowing the student to become familiar with these essential concepts on their own. These terms are followed by a description of the procedures the student needs to follow in order to complete the lab by direct control (if they are in the EAAL), or by net control (if they are at a remote site).

The student can then read the instructions that apply to Lab 506. The advantage to this approach is that the student can study the lab procedures off-line before the lab, enabling them to spend less time on the actual lab procedures because they are already familiar with the instructions, terms, and procedures. This makes much more effective use of their actual lab use time.

Students may also view the EAAL setup for the experiment they are conducting. The lab contains a small camera which provides continuously updated image frames which may be viewed over the Web, allowing the student to obtain visual feedback on the process. Although these images are not real-time (only a few frames per minute), they do at least allow the student to verify that the expected operation has happened (see figure 5). The student may also view still images from the Blob Lab camera (see Figure 6).

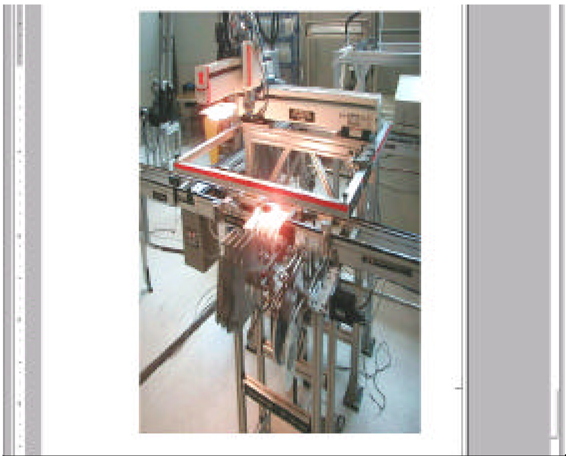

Figure 5. Still Image Frame of Blob Lab Robot

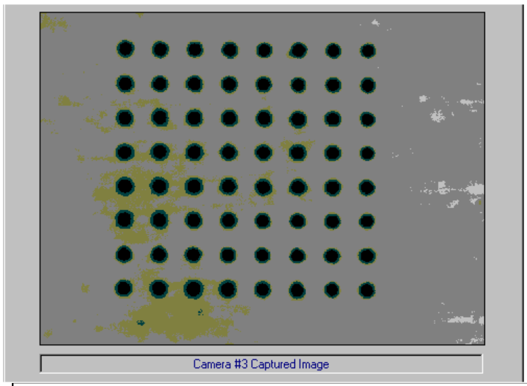

Figure 6. Blob Lab Camera Image showing a printed-circuit-board calibration array.

7. Conclusion

Since the completion of the test case "Blob Lab", several other web-based labs have also been completed and used by students in multiple classes. Although there have been several problems, they have generally fallen into the category of miscommunication, common to distance education experiences. On-line labs have an even-greater need to be very clear, due to the interactive nature of the distance education experience.

In spite of the challenges that have occurred, it is presently the consensus of faculty, lab assistants, and students alike that the on-line experience is a satisfactory way to share limited resources, and to make such resources available to a wider audience. The Blob Lab, along with the others currently developed, may be viewed at http://research.et.byu.edu/eaal/html/education.html.

References

[1] Henry, Jim, "Running Laboratory Experiments Via the World-Wide Web", ASEE Annual Conference Proceedings, Seattle, WA; Jun 1998.

[2] Shen, Hong, Zheng Xu, B. Dalager, V. Kristiansen, Ø Strøm, Michael S. Shur, Tor A. Fjeldly, Jian-Qiang Lü, and T. Ytterdal, "Conducting Laboratory Experiments over the Internet," *IEEE Transactions on Education*, vol 42, No. 3, Aug 1999; pp 180-185.

[3] Lunt, Barry and Scott Tucker, "Web Lab Issues," 24th Annual Engineering Technology Leadership Institute (ETLI), St. Louis, MO; Nov 1998.

[4] Galvin, Robert W., "Improving Manufacturing Education is a Competitive Advantage: Ignoring it is a Competitive Risk," *Keynote Address*, 1997 SME Manufacturing Education Conference, Washington, DC, June 1997.